FEASIBILITY OF ESTIMATING DIRECT MORTALITY AND INJURY ON JUVENILE SALMONIDS PASSING THE DALLES DAM SPILLWAY DURING HIGH DISCHARGE

Contract No. DACW68-96-D-0003
Task Order DT04

December 2001

NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS

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EXECUTIVE SUMMARY

The U. S. Army Corps of Engineers (Corps), Portland District, Oregon sponsored an investigation to determine the feasibility of estimating survival (direct effects) and injury rates of juvenile salmonids upon passage through high discharge (30 to 40% of the total river flow) spillbays at The Dalles Dam using the HI-Z Turb'N tag (balloon tag) recapture methodology. The spillbay investigation was conducted from 22 May through 25 May 2001; fish were passed through Spillbays 4, 9, and 11. Spill rate was set at 40% of the total river flow on 22 and 23 May and 30% on 24 and 25 May. Total spill rates tested were 58, 69, 54, and 51 kcfs. Additionally, the Corps desired to gather preliminary data on the condition of juvenile salmon passed through the sluice. Recapture rate and the condition of the sluice passed fish was determined on 8, 9, and 11 May at a discharge rate of 5.4 kcfs. Because the study was not designed to estimate survival, control fish were not released. Fish released through the spillbays were examined immediately upon recapture and released while 48 h delayed effects of sluice passage were obtained by holding fish in pools.

Rainbow trout obtained from the Troutlodge Hatchery in Soaplake, Washington and subyearling chinook salmon from Spring Creek National Fish Hatchery were used for the spillbay evaluation. Juvenile chinook salmon used for the sluice evaluation were obtained from the Carson National Fish Hatchery, Bingen, Washington. Ambient water temperature during the investigation ranged from 12.5 to 15.0°C (54.5 to 59.0°F).

Three size groups (90 to 102 mm, 115 to 140 mm, and 141 to 184 mm) of fish were passed through the spillbays. The respective sample sizes were 25, 25, and 100 fish. Some 200 fish (132 to 180 mm, mean 149 mm) were released through the sluice.

Additionally, Normandeau Associates, Inc. assisted Pacific Northwest National Laboratory (PNNL) with the deployment and recapture of sensor fish (an instrumental package designed to determine fish exposure history to hydraulic parameters along a passage route). Sensor fish were released through Spillbays 4 (40 fish), 9 (39 fish), and 11 (28 fish), and the sluice (2 fish). Results of the sensor fish releases will be reported separately by PNNL.

Recapture rates (all fish size groups) for fish passed through Spillbays 4, 9, and 11, were 90, 95, and 87%, respectively. Physical recapture rate of the three size groups of fish passed through the spillbays was high (≥95%) for all but the smallest size group (72%). Average time from release until recapture was 15 min for the small fish and <8 min for the other size groups. Some 8.8% (12 of 137 fish) of the spillway exposed fish exhibited injuries (hemorrhaged eyes, scrapes, hemorrhaged gills, torn opercula). The highest injury rate (14%, 8 of 57 fish) was observed at Spillbay 9 and least (1%, 1 of 54 fish) at Spillbay 4.

Recapture rate of sluice passed fish was 97% (194 of 200 fish). Most sluice passed fish were recaptured in less than 10 min. Four of the 194 recaptured fish had visible injuries, but the injury (bulging eye) on only one fish could be attributed to sluice passage. The paucity of injuries (1 of 194 fish or 0.5%) that could be attributed to sluice passage indicates that this passage route is quite benign and previously reported high sluice mortality (direct and indirect) at The Dalles sluice may be due to other factors (*e.g*, predation).

The balloon-tag recapture technique can be used to rapidly assess fish injury and mortality at high spill rates, particularly for fish >100 mm long, at The Dalles Dam. The balloon tags can also be used to estimate survival and injury rates for fish <100 mm long but a larger sample size may be needed (because of lower recapture rates) to provide a high precision level. Sample size requirements would be considerably lower for larger sized fish (observed high recapture rates).

The results of this feasibility study indicate that the incidence and severity of injury differs between spillbays and spill rates. We recommend a full scale field test be conducted in conjunction with hydraulic modeling to ascertain possible causes for preliminary differences observed in injury rates for the spillbays, particularly the difference noted between Spillbays 4 and 9.

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APPENDIX A

1.0 INTRODUCTION

Historically, spillways and sluiceways at hydroelectric dams were constructed as conduits for transporting excess river flow or debris with little focus on their potential for safe fish passage routes. In recent times, however, these conveyances are increasingly viewed as viable fish passage routes and are used to increase survival for the declining salmonid populations. Consequently, at hydro dams on the Columbia River Basin, spill is used to enhance fish passage with the assumption of an overall improvement in survival of juvenile emigrating salmonids because of greater fish passage effectiveness and reported higher survival (Schoeneman *et al.* 1961; Heinle and Olson 1981; Wilson *et al.* 1991). Recent survival estimates of emigrating fish in passage through non-turbine exit routes at hydro dams have shown much variation depending upon the passage route and its configuration, spill volume, top or bottom spill, obstructions in flow path, and species (Muir *et al.* 2001, and Table 1-1). Survival estimates (direct effects) of juvenile salmonids passed through spillbays and bypasses at several hydroelectric dams on the Columbia River have ranged from 92 to 100% (Table 1-1).

In lieu of juvenile bypass facilities at The Dalles Dam, regional fisheries managers have recommended maximizing spill to increase fish passage efficiency (FPE) and presumably improve project survival. National Marine Fisheries Service (NMFS) and Northwest Power Planning Council set fish passage efficiencies (non-turbine passage) at 80% for The Dalles Dam and other dams on the Columbia and Snake Rivers (Whitney *et al.* 1997). As a result, 64% of total river flow at The Dalles Dam has been spilled from 1995 through 1997 to enhance the probability of achieving the 80% FPE. Although FPE values close to the target goal of 80% have been attainable with high spill rates at The Dalles, fish survival can be less than 98% (target value) and may be negatively impacted by high spill volume and its attendant pattern (Dawley *et al.* 1998). Hansel *et al.* (2000) estimated FPEs from 73.5 to 95.3% in 1999, depending upon spill rate (30 or 64%), spill pattern, and species. The Dalles Dam stilling basin is relatively shallow, and a large volume of water can be spilled without increasing total dissolved gas (TDG) levels above 120%.

Normandeau Associates *et al.* (1996b, see Table 1-1) reported survival (direct effects) of juvenile chinook salmon (average 130 mm) at The Dalles spillway at 95.5% in passage through a standard spillbay; 94% of the fish were recaptured. However, the investigation was conducted at lower spill rates (4,500 to 10,000 cfs total discharge) than currently envisioned for juvenile safe fish passage. From 1997 to 2000, the NMFS estimated survival (direct and indirect effects) at The Dalles Dam using passive integrated transponder (PIT) tagged smolts and found that spill rate affected survival, with higher survival at 30% spill than at 64% spill (Independent Scientific Advisory Board 2000 and Dawley *et al.* 2000). The 40% spill rate tested in 2000 provided survival rates similar to those seen under the 30% spill. NMFS also found that survival for subyearling chinook was consistently higher at night than in the day. This trend was not consistently seen with spring migrants. For all other variables examined (*i.e.*, tailwater elevation, spill volume, temperature) no correlation was found. Although survival of spilled fish is improved at 30 to 40% spill rate, it is still unacceptably low for a primary passage route. In addition, turbine survival (81 to 84%) is lower than would be expected based on survival seen at other dams (Counihan *et al.* 2001).

Because of these lower than desirable survival rates the Corps redirected the emphasis of biological evaluations at The Dalles Dam from developing point survival estimates under various operating conditions to identifying mechanisms contributing to mortality and then look for ways to minimize or eliminate mortality from those mechanisms. There are three current hypotheses for spillway and turbine mortality: 1) mechanical factors in the spillway tailrace (or turbine unit); 2) predation downstream of the project; and 3) a combination of mechanical injury and predation. Earlier investigations using balloon tag recapture have provided useful information in identifying injury/mortality mechanisms (Normandeau Associates *et al.* 1996a,d, 2000a,b; Mathur *et al.* 1996a,b).

1.1 Study Objectives

The objectives were to: 1) evaluate the feasibility of obtaining direct mortality and injury to juvenile salmon at high spill rates using the balloon tag-recapture technique; 2) obtain preliminary information on the condition (mortality/injury) of juvenile salmon passed through the sluice at normal discharge; and 3) assist Pacific Northwest National Laboratory (PNNL) with the release and recapture of sensor fish through three spillbays with spill at 40% of the total river flow.

1.2 Project Description

The Dalles Dam is the second dam upriver (river mile 191.5 or rkm 306) on the main stem Columbia River (Figure 1-1). The powerhouse was completed in 1957 and is located between Oregon and Washington. The Dalles Dam consists of a powerhouse, a spillway, and a navigation lock. The configuration of this facility is such that the spillway is perpendicular to the river, while the powerhouse is parallel to the river. The spillway has an overall length of 1,370 ft and contains 23 gates, each 50 ft wide. Spill is regulated by bottom opening tainter gates that pass water at a maximum depth of approximately 40 ft below the upstream water surface. Water discharged through the tainter gates plunges approximately 50 ft to the stilling basin. A single row of 9 ft high by 10 ft wide concrete baffles are located in the stilling basin to dissipate energy. An end sill lies downstream of the baffles; this structure is a 13 ft high continuous vertical wall and lies approximately 10 ft below normal tailrace elevation (Figure 1-2).

2.0 STUDY DESIGN

There are two primary components of effects on fish using any exit route: direct and indirect effects. Direct effects are manifested immediately after passage (*e.g.*, instantaneous fish mortality, injury, loss of equilibrium); indirect effects (*e.g.*, predation, disease, physiological stress) may occur over an extended period or distance after passage. The most straightforward approach to estimating the direct effects of passage is to introduce a known number of marked live fish into a passage route, recapture them immediately after passage, enumerate the live and dead fish, and carefully examine the condition of each fish. The present study was designed to determine 1) the feasibility of estimating the direct effects of spillway passage at The Dalles Dam at relatively higher spill rates than tested earlier (Normandeau Associates *et al.* 1996b) and 2) the condition of fish passed via the sluice.

2.1 Source and Maintenance of Specimens

The sluice investigation utilized juvenile chinook salmon (132 to 180 mm, average of 149 mm) obtained from the Carson National Fish Hatchery, Bingen, Washington. Approximately 300 fish were transported via truck to the spillway deck of The Dalles Dam and were held in two tanks, each with a 200 gal capacity. Subyearling chinook salmon (small fish, 90 to102 mm, average 94 mm) and rainbow trout (mid size fish ranged from 115 to 140 mm, average 130 mm and large size fish ranged from 141 to 184 mm, average 162 mm) were used for the spillway study. The spring chinook salmon were obtained from Spring Creek National Fish Hatchery, Washington and the rainbow trout were obtained from the Troutlodge Hatchery located in Soaplake, Washington. Fish holding tanks were supplied continuously with ambient river water. Fish were held for a minimum of 24 h prior to tagging in order to alleviate handling stress and to acclimate them to ambient river conditions. Ambient river temperature during the study ranged from 12.5 to 15.0°C (54.5 to 59.0°F).

Individual treatment fish on any given day were drawn non-selectively from a supply tank, thereby assuring that all groups were of similar size and condition. Lots of 5 to 10 fish were randomly netted from the holding tank and transferred to the adjacent tagging site with a water-sanctuary equipped net. Fish displaying abnormal behavior, severe injury, fungal infection, or descaling (>20% per side) were not used. The same fish selection criteria were applied for all of the treatment groups.

2.2 Tagging and Release

Fish handling and tagging techniques followed those previously used at Corps projects and similar passage survival investigations of juvenile salmon on the Columbia River Basin (Mathur *et al.*1996b, 1999; Normandeau Associates and Skalski 1999, 2000a). Briefly, while anesthetized in 0.5% MS-222 smaller fish (<102 mm) were equipped with a single uninflated balloon tag and larger fish (≥110 mm) with two uninflated balloon tags. All fish were also equipped with a miniature radio tag attached by a stainless steel pin inserted through the musculature beneath the dorsal fin (Heisey *et al.* 1992) with the exception of nine smaller trout (118 to 132 mm) which had a Lotek nano tag (14 by 6 mm, 0.9 g in weight) inserted into the stomach. A portion of the fish received an identifying fin clip for post-passage assessment. Balloon tagged fish were placed in a covered, 20 gal container continually supplied with ambient river water until fully recovered from anesthesia (generally 30 to 45 min, minimum 20 min). After full recovery, fish were individually placed into the induction system, tags were activated, and the fish was released.

The induction system consisted of a small holding basin attached to a 4 in diameter flexible hose (Normandeau Associates and Skalski 1999, 2000a; Normandeau Associates *et al.* 1996a,b,c), which was supplied with river water to ensure fish were transported quickly within a continuous flow of water. Inflation time of the tags was partially regulated by the temperature and amount of water injected into the tags just prior to release. At the spillbay release sites, the flexible hose was positioned and supported within a 6 in diameter steel pipe. The terminus of the hose passed through a 6 in diameter 30° elbow and was pointed downstream 3 ft above the crest elevation of the spillbays (Figures 2-1 and 2-2). The steel pipe was installed at the center of the spill bay and was secured with guide wires and anchored to the concrete head works. A similar procedure was successfully employed at the Lower Granite and Wanapum dams (Normandeau Associates *et al.* 1996a, 2000a).

The bypass sluice (Figure 2-3) was evaluated by releasing the fish at the downstream entrance to the sluiceway collection channel. The 4 in release hose was supported via an iron frame which positioned the terminus of the hose approximately 1 ft above the water surface (Figure 2-2).

All procedures for handling, tagging, release, and recapture of fish were nearly identical for all treatment groups. No control fish were released for either the sluice or spillbay evaluation since obtaining survival estimates was not an objective of the present study.

A total of 200 chinook salmon was released through the bypass sluice (Table 2-1). The feasibility study at the spillbays utilized 25 chinook salmon and 125 rainbow trout. Some 10, 10, and 5 chinook salmon were released through Spillbays 4, 9, and 11, respectively. The respective distribution of the rainbow trout was 50, 50, and 25 fish through the three spillbays (Table 2-2).

2.3 Release Conditions

Fish were released into the sluice collection channel on 8, 9, and 11 May 2001. The discharge during these releases was 5.4 kcfs. The total discharge at The Dalles ranged from 100.5 to 151.1 kcfs during the conduct of the study. Forebay and tailrace elevations ranged from 157.7 to 159.1 ft and 76.0 to 77.9 ft, respectively (Table 2-3 and Appendix Table A-1).

The spillbay tests were conducted on 22 through 25 May 2001 (Table 2-3 and Appendix Table A-1). Spill was set at 40% of the total river flow on 22 and 23 May and 30% of the total river flow on 24 and 25 May, resulting in total spill volumes of 58, 69, 54, and 51 kcfs, respectively. Discharge was highest (4.5 to 7.4 kcfs) at Spillbay 4 and lowest (3.0 to 4.5 kcfs) at Spillbay 11. Discharge through Spillbay 9 was 4.5 kcfs on all testing days. Total project discharge during testing ranged from 140.6 to 183.2 kcfs (Figure 2-4).

2.4 Fish Recapture

Fish were tracked and retrieved when buoyed to the surface downstream of the sluice and spillbays by one of three recapture boat crews. Boat crews were notified of the radio tag frequency of each fish upon its release. Only crewmembers trained in fish handling were used to retrieve tagged fish. Radio signals were received on a 5-element Yagi antenna coupled to an Advanced Telemetry receiver. The radio signal transmission enabled the boat crew(s) to follow the movement of each fish after sluice or spillway passage and position the boats downstream for retrieval when the balloon tag buoyed the fish to the surface; the boats were required to remain a safe distance downstream of the turbulent discharge. Active radio tags which failed to surface were tracked for a minimum of 30 minutes and then periodically thereafter to ascertain if fish displayed movement patterns typical of emigrating smolts or that of a predator. Recaptured fish were placed into an on-board holding facility, and tags were removed (Heisey *et al.*1992). Each fish was examined for descaling and injuries and assigned appropriate condition codes, if necessary, per the descriptions presented in Table 2-4. Injury and descaling were categorized by type, extent, and area of body the injury occurred. Tagging and data recording personnel were notified via a two-way radio system of each fish's recovery time and condition. Upon recapture and removal of balloon and radio tags, spring chinook salmon utilized for the spill study were released to the Columbia River; recaptured rainbow trout were not released back into the river.

Recaptured live fish utilized in the sluice evaluation were transferred in 5 gal pails to an on-shore holding tank for assessment of delayed effects (48 h). Tanks were continuously supplied with ambient river water and shielded to prevent potential fish escape and avian predation. The sluice fish were re-examined for descaling and injury at the end of the 48 h delayed assessment period and then released to the river.

2.5 Classification of Recaptured Fish

As in previous similar investigations (Heisey *et al.* 1996; Normandeau Associates and Skalski 1998, 1999, 2000a,b,c) the immediate post-passage status of an individual recaptured fish and recovery of inflated tags dislodged from fish was classified as alive, dead, inflated tag(s) recovered, unknown, or predation. The following criteria have been established to make these designations: (1) alive--recaptured alive and remaining so for 1 h; (2) alive--fish does not surface but radio signals indicate movement patterns typical of emigrating juveniles; (3) dead--recaptured dead or dead within 1 h of release; (4) dead--only inflated tag(s) without fish are recovered and telemetric tracking, or the manner in which inflated tags surfaced, is not indicative of predation; (5) unknown--no fish or dislodged tags are recaptured, or radio signals are received only briefly, and the subsequent status cannot be ascertained; and (6) predation--fish are either observed being preyed upon, the predator is buoyed to the surface, or subsequent radio telemetric tracking indicates predation (*i.e.*, rapid movements of tagged fish in and out of turbulent waters or sudden appearance of fully inflated tags). Preyed upon fish are assumed dead in the survival calculations.

2.6 Mortality and Injury

Although direct mortality estimates of the sluice and spillbay passed fish was not an objective of this evaluation, the immediate status (alive/dead) of all fish was recorded upon recapture. The condition (incidence of injury and/or loss of equilibrium) of all fish was recorded upon recapture. Fish without any visible injuries that were not actively swimming were classified as “loss of equilibrium”. This condition has been noted in previous studies (RMC *et al.*1994; Normandeau Associates *et al.* 1996a,b,c,d) and often disappears within 10 to 15 min after recapture if the fish is not injured. Sluice-passed fish were held for 48 h and then re-anesthetized to assess their condition and delayed effects of passage.

The re-examination of immobilized fish minimizes the need for extensive handling and associated stress upon immediate recapture. The initial examination allows detection of some injuries, such as bleeding and minor bruising that may not be evident after 48 h due to natural healing processes (Normandeau Associates *et al.* 1996a,c). Injury and descaling were categorized by type, extent, and area of body.

2.7 Analysis

Differences between recapture rates and injury rates of fish between spillbays and across size groups were evaluated using Fisher's Exact Test. Confidence limits were calculated for percentages based on the binomial distribution. Statistical output is presented in Appendix B.

2.8 Sensor Fish

Sensor fish, an instrumented package designed to determine exposure histories to turbulence and pressure during passage (PNNL *et al.* 2001) were also released through Spillbays 4, 9, and 11, and the sluice. Some 40, 39, and 28 sensor fish were released through Spillbays 4, 9, and 11, respectively, via the same induction system used to release alive fish. Two sensor fish were released through the sluice. The sensor fish were equipped with three balloon tags and a radio tag, which facilitated recapture from the tailwater after passage. The results of sensor fish passage will be provided by PNNL in a separate report. Only preliminary results (Section 3.3) and plots on four sensor fish are presented within this report (Appendix C).

3.0 RESULTS

3.1 Fish Recapture

3.1.1 Sluice Passage

Recapture rate (physical retrieval of both alive and dead fish) of the sluice passed fish was 97% (194 of 200; Table 2-1). The status of the 6 non-retrieved fish was as follows: dislodged balloons from 1 fish, 2 unknown, and 3 were trapped in the back-roll of the sluice exit. The trapped fish could not be safely retrieved without decreasing or curtailing the sluice discharge. Two of the 194 recaptured fish were dead; one was observed being carried on shore by a black bird.

Recapture time (the time interval between release through the induction system until the fish was retrieved) ranged from 1 to 243 min with an average and median of 11 and 6 min, respectively (Figure 3-1). Two fish were retained in the outfall area for 2 to 4 h before moving downstream. Excluding these two fish, the average and median recapture times were 9 and 6 min, respectively.

3.1.2 Spillbay Passage

Across all spillbays, recapture rates differed significantly ($P \leq 0.0035$) with fish size (Table 3-1 and Appendix B). The rates were 72% (18 of 25), 96% (24 of 25), and 95% (95 of 100) for the small, mid, and large size groups of fish, respectively. Across all fish sizes the recapture rates for Spillbays 4, 9, and 11 (regardless of size) were 90, 95, and 87%, respectively. These rates were not significantly different ($P=0.3574$).

Average retrieval was longest (15 min) for the small fish and similar (<8 min) for the other sizes (Figure 3-2). Retrieval time was shortest for fish passed through Spillbay 4 (average 7.4 min) and longest for fish passed through Spillbay 11 (average 10.2 min).

The retention rate of the nano tags placed in the stomachs of nine smaller trout was 33% (3 of 9 fish). Three fish lost the small radio tag prior to release, two fish lost the tag during spillbay passage but were still recaptured, and one fish was never recaptured (Appendix Table A-3).

3.2 Injury

Injured fish were divided into two basic groups, fish with visible injuries (lacerations, missing or bulging eyes, hemorrhaging, bruises, etc.) and those with either descaling or loss of equilibrium.

3.2.1 Sluice Passage

Four of the 194 recaptured sluice passed fish has visible external injuries and two other fish were uninjured but displayed temporary loss of equilibrium (Table 3-2 and Appendix Table A-4). However, the injury or loss of equilibrium could be attributed to sluice passage for only one fish exhibiting a hemorrhaged left eye (Figure 3-3). Four incidences of injury/loss of equilibrium appeared to be inflicted when buoyed fish became entrapped along the shoreline among rocks or in a fishing net. Visible external injuries on two of these fish consisted of minor scrapes and bruises and were not lethal. The remaining fish had bird bill marks across it’s back, which were fatal.

3.2.2 Spillbay Passage

A total of 12 of the 137 recaptured fish (8.8%) exhibited some type of injury (Table 3-2 and Appendix Table A-5). All of these injuries appeared to be attributed to spillbay passage. The highest incidence of injury occurred at Spillbay 9 where 8 of 57 (14.0%, 90% CI=7.4 to 24.3%) of the recaptured fish were injured. Injury rate was 11.5% (90% CI=3.6 to 27.9%) (3 of 26 fish) and 1.8% (90% CI=0.1 to 9.3%) (1 of 54 fish) at Spillbays 11 and 4, respectively.

Injury rate varied for the three size groups of fish. Two of the 18 recaptured (11.1%, 90% CI=2.4 to 32%) small chinook salmon were injured; both had hemorrhaged eyes and had been passed through Spillbay 9 (Table 3-1).

Three of the 24 (12.5%, 90% CI=3.9 to 30.0%) recaptured mid-sized rainbow trout had visible injuries (Table 3-1). Two of these fish sustained scrapes on the top of the head or snout (Figure 3-3); the other fish had hemorrhaged left gills. These 3 injured fish had passed through Spillbay 4 (1 of 12 fish) and Spillbay 11 (2 of 4 fish).

Seven of 95 (7.4%, 90% CI=3.7 to 13.7%) large rainbow trout were visibly injured upon recapture (Table 3-1). Injury types included scrapes on the head or body, hemorrhaged gills, hemorrhaged eyes, and torn operculum(s). The incidence of injured large fish was highest (14.6%) at Spillbay 9 (6 of 41 recaptured fish).

Injury rate was not significantly different (P=0.5668) for the three size groups or between the three spillbays (P=0.0503).

3.3 Sensor Fish - Spillbays

Preliminary data from the sensor fish passed through the spillbays support the data obtained on spillbay-passed balloon tagged fish. Sensor fish passed through Spillbays 9 and 11 generally were exposed to more severe hydraulic conditions than those passed through Spillbay 4. Spillbay 9 and 11 sensor fish sounded and made rapid velocity changes approximately two to three times more frequently than the sensor fish passed through Spillbay 4 (Appendix C). Retention time in the spill basin appeared to be a factor in the duration and severity of the hydraulic forces that impacted the sensor fish.

4.0 DISCUSSION

The primary objectives of the study were met. The use of the balloon tag technique would be feasible for readily obtaining direct mortality and injury to juvenile salmonids, particularly those longer than 100 mm, passed at high spill rates (30 to 40% of the total river flow, 51 to 69 kcfs spill rate). The high recapture rate (≥95%) of the larger fish (115 to 184 mm) indicates that mortality/injury data should be attainable on the size of fish typical during the spring run and at spill of at least 70 kcfs.

Based on the recapture boats access to the balloon tagged fish buoyed to the surface after spillbay passage, higher spill should not appreciably hinder fish recapture. As the spill rate increases the recapture boats can take up positions further downstream and/or move into the sheltered south channel. Balloon tagged fish have been readily recaptured (≥95%) from the tailwaters of the Rocky Reach and McNary projects with spills of approximately 200 and 100 kcfs and attendant high turbulence, respectively (Normandeau and Skalski 1996; Normandeau Associates *et al.* 1999).

Passage survival estimates with a precision level of ±0.03, 90% of the time, should be attainable with approximately 400 fish per treatment condition based on ≥95% recapture rates and expected passage and control survival rates of 98 and 99%, respectively.

The present study also indicates that spillway passage inflicted injury/mortality rates on smaller sized (approximately 90 to 100 mm) salmon, typical summer run fish, can be obtained at high spill; however, the sample size may need to be substantially increased depending on desired precision. The relatively low (72%) recapture rate of the small size (90 to 102 mm) chinook salmon was determined with only 25 fish. A shift in recapture of a few fish would markedly influence the recapture percentages. Fish smaller than 100 mm have been successfully balloon tagged and recaptured at high rates (>90%) but these fish were released in lower discharge rates than envisioned at The Dalles.

The effects of passage were not the same for the three spillbays. Conditions at Spillbay 9 appeared to be most detrimental to passed fish of the three tested spillbays. Injury rate was highest (14%) and hydraulic forces experienced by the sensor fish were most severe at Spillbay 9 (see Appendix B). Some of the sensor fish passed through Spillbay 9 reportedly sounded (>5 times) and were subjected to rapid drastic changes in their velocity vectors for about 100 seconds. This contrasts to a 1.8% injury rate observed for fish at Spillbay 4; additionally sensor fish at Spillbay 4 were exposed to the turbulent hydraulic conditions for only about 20 seconds.

Preliminary estimates of condition (number dead and/or injured) were determined for juvenile chinook salmon passing the sluice, discharging approximately 5.4 kcfs, and juvenile chinook salmon and rainbow trout passing through Spillbays 4, 9, and 11 at a relatively high discharge rate (51 to 69 kcfs).

The actual path traversed by each fish in the sluice study is unknown; however, the fish were released far enough upstream of the sluiceway exit to allow the fish to potentially enter any part of the discharge jet. Fish entrained in the periphery of the jet should be subjected to the highest region of shear, turbulence, deceleration, and energy dissipation, especially when the jet first intercepts the receiving waters (PNNL *et al.* 2001). Although the periphery can be potentially hazardous to passed fish, this area is a relatively small portion of the total jet cross-section area. If fish were uniformly distributed within a discharge jet then most of the fish would not be subject to adverse hydraulic forces in the periphery.

The low incidence of injuries to fish passed through the sluice at The Dalles indicates that nearly all of the entrained fish encountered impact velocity within their tolerance range and did not collide with solid objects in the receiving water. If the naturally entrained fish encounter similar conditions their passage should prove to be virtually benign as well. Based on field and laboratory tests on fish subjected to periphery regions of a discharge jet by (PNNL *et al.*2001), little to no injury (<1%) was observed on juvenile salmon at entry velocities ≤50 ft/s. In another study, Normandeau Associates and Skalski (2000c) found 100% survival and no injuries to juvenile salmon subjected to 49 ft/s entrance velocity upon exiting a free-falling bypass pipe at Wanapum Dam. Tailrace entrance velocity of the discharges from both the sluice and the spillbays was estimated to be near 60 ft/s (Corps, personal communication).

5.0 CONCLUSIONS

The balloon tag-recapture technique can be used to estimate direct mortality and injury at high spill rates. However, a limited sample size (N=25) of small sized fish (≤102mm) creates some uncertainty as to whether a full-fledged survival study of small fish at high spill rates can be undertaken without a larger sample size (>300 fish) than has been typically used in previous balloon tag studies.

The spillbays inflicted considerably more injury than the sluice, especially Spillbay 9. The data are supported by that gathered from the sensor fish. Incidence of sensor fish making repeated soundings and drastic, frequent velocity vector changes was higher at Spillbays 9 and 11 than at Spillbay 4. The timing of apparent strike events coincided with passage into the spill basin where two sets of energy dissipation structures (baffles and end sill) intercept the discharge.

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TABLES

Table 1-1

Sample size, recapture and control survival rates, and estimated 48 h survival (direct effects) of anadromous fishes in passage through non-turbine exit routes at hydroelectric dams. Estimates based on balloon tag-recapture methodology (Heisey *et al.* 1992).

Station	Exit Route	Species	Sample Size	Head (ft)	Test Discharge (cfs)	Recapture Rates (%) Control	Recapture Rates (%) Treatment	Control Survival (%)	Passage Survival (%)	Source
Crescent, NY	Spillway	Juvenile herring	110	13	40	90.0	93.6	82.1	88.3	Mathur *et al.* (1996a)
Cabot, MA	Sluice	American shad	150	69	225	96.0	96.0	93.9	98.3	NAI (1995)
Bellows Falls, VT	Sluice	Atlantic salmon	100	59	300	99.0	95.0	100.0	96.0	Heisey *et al.* (1993)
Vernon, VT/NH	"Fish tube" (Sluice)	Atlantic salmon	100	27	40	100.0	93.3	100.0	93.3	Heisey *et al.* (1996)
Wilder, VT	Sluice	Atlantic salmon	100	52	200	99.0	100.0	99.0	97.0	Heisey *et al.* (1993)
	Sluice	Atlantic salmon	45	52	300	100.0	97.8	100.0	91.0	Heisey *et al.* (1993)
	Sluice	Atlantic salmon	100	52	500	99.0	99.0	99.0	97.0	Heisey *et al.* (1993)
The Dalles, WA	Spillway	Chinook salmon	270	81	10,500	97.0	94.1	97.0	95.5	NAI *et al.* (1996b)
	Spillway[b]	Chinook salmon	271	81	10,500	97.0	97.4	97.0	99.3	NAI *et al.* (1996b)
	Spillway[b]	Chinook salmon	210	81	4,500	96.2	94.3	96.2	99.0	NAI *et al.* (1996b)
Wanapum, WA	Sluice	Chinook salmon	195	79	2,000	100.0	97.9	100.0	97.4	NAI *et al.* (1996a)
	Spillway	Chinook salmon	235	79	4,300	100.0	99.6	99.6	99.6	NAI *et al.* (1996a)
	Spillway[a]	Chinook salmon	235	79	4,300	100.0	97.9	99.6	95.7	NAI *et al.* (1996a)
	Spillway[b]	Chinook salmon	155	79	2,000	100.0	97.4	100.0	92.0	NAI *et al.* (1996a)
	Spillway[b]	Chinook salmon	160	79	4,000	96.7	98.8	96.7	96.9	NAI *et al.* (1996a)
	Spillway	Chinook salmon	180	82	2,800	100.0	100.0	94.5	100.0	NAI and Skalski (1999)
	Spillway	Chinook salmon	244	82	6,000	100.0	99.6	95.8	99.3	NAI and Skalski (1999)
	Spillway	Chinook salmon	130	82	11,500	98.4	99.2	94.3	94.6	NAI and Skalski (1999)
	Spillway[a]	Chinook salmon	200	82	2,800	100.0	100.0	96.5	99.0	NAI and Skalski (1999)
	Spillway[a]	Chinook salmon	199	82	6,000	100.0	98.5	95.3	97.6	NAI and Skalski (1999)
	Spillway[a]	Chinook salmon	191	82	11,500	98.4	96.7	94.3	92.8	NAI and Skalski (1999)
	Spillway	Chinook salmon	180	82	2,800	100.0	100.0	97.5	99.4	NAI and Skalski (2000b)
	Spillway	Chinook salmon	169	82	6,000	100.0	100.0	95.8	97.6	NAI and Skalski (2000b)
	Spillway	Chinook salmon	198	82	7,500	100.0	100.0	94.3	99.5	NAI and Skalski (2000b)
	Spillway[a]	Chinook salmon	180	82	2,800	100.0	100.0	96.5	98.3	NAI and Skalski (2000b)
	Spillway[a]	Chinook salmon	170	82	6,000	100.0	98.8	95.3	98.2	NAI and Skalski (2000b)
	Spillway[a]	Chinook salmon	210	82	7,500	100.0	99.0	82.3	97.6	NAI and Skalski (2000b)
	Bypass Pipe	Chinook salmon	500	76-80	420	99.6	99.8	99.6	100.0	NAI and Skalski (2000c)
Bonneville, WA	Spillway	Chinook salmon	280	60	12,000	96.1	96.8	96.1	100.0	NAI *et al.* (1996c)
	Spillway[a]	Chinook salmon	280	60	12,000	96.1	99.3	96.1	100.0	NAI *et al.* (1996c)
Lower Granite, WA	Spillway[a]	Chinook salmon	120	90	3,400	100.0	100.0	100.0	97.5	Mathur *et al.* (1999)
	Surface Bypass Collector[a]	Chinook salmon	120	90	3,400	100.0	99.2	100.0	95.8	Mathur *et al.* (1999)
	Spillway[a]	Chinook salmon	130	90	3,400	92.1	94.6	92.1	97.6	NAI *et al.* (2000a)
	Surface Bypass Collector[a]	Chinook salmon	133	90	3,400	92.1	97.8	92.1	97.0	NAI *et al.* (2000a)

Table 1-1

Continued.

Station	Exit Route	Species	Sample Size	Head (ft)	Test Discharge (cfs)	Recapture Rates Control	Recapture Rates Treatment	Control Survival	Survival (%)	Source
Little Goose, WA	Spillway	Steelhead	150	90	5,600	100.0	100.0	100.0	100.0	NAI *et al.* (1997)
	Spillway	Steelhead	150	90	9,500	100.0	100.0	100.0	100.0	NAI *et al.* (1997)
	Spillway	Steelhead	100	90	1,800	99.0	100.0	99.0	100.0	NAI *et al.* (1997)
	Spillway[c]	Steelhead	40	90	5,600	100.0	98.0	100.0	100.0	NAI *et al.* (1997)
	Spillway[c]	Steelhead	120	90	9,500	100.0	99.0	100.0	98.3	NAI *et al.* (1997)
	Spillway[a]	Steelhead	150	90	5,600	100.0	99.0	100.0	98.0	NAI *et al.* (1997)
	Spillway[a]	Steelhead	150	90	9,500	100.0	100.0	100.0	100.0	NAI *et al.* (1997)
	Spillway[a]	Steelhead	100	90	1,800	99.0	100.0	99.0	99.0	NAI *et al.* (1997)
	Spillway[a,c]	Steelhead	39	90	5,600	100.0	100.0	100.0	100.0	NAI *et al.* (1997)
	Spillway[a,c]	Steelhead	120	90	9,500	100.0	99.0	100.0	99.2	NAI *et al.* (1997)
Rock Island, WA	Spillway[b,d]	Chinook salmon	250	41	1,850	NA	98.0	NA	95.1	NAI and Skalski (1998)
	Spillway[b]	Chinook salmon	250	41	10,000	NA	100.0	NA	98.4	NAI and Skalski (1998)
	Spillway[b]	Chinook salmon	200	41-49	2,500	100.0	99.5	99.5	99.5	NAI and Skalski (2000a)
	Spillway[b]	Chinook salmon	200	41-49	10,000	100.0	100.0	99.5	99.5	NAI and Skalski (2000a)
	Spillway[a,b,e]	Chinook salmon	200	40-43	2,500	100.0	99.5	100.0	99.0	NAI and Skalski (2001)
	Spillway[a,b]	Chinook salmon	200	40-43	2,500	100.0	100.0	100.0	100.0	NAI and Skalski (2001)

a Spillbay with flow deflector.
b Overflow weir or slot to attract surface oriented juvenile salmonids.
c Fish released into head pond vortices upstream of tainter gates.
d Spill directed onto concrete slab; survival is relative to survival at another spillbay.
e Periphery release.

Table 2-1

Daily tag-recapture data for chinook salmon smolts passed through the sluice at The Dalles Dam, May 2001. Proportions given in parentheses.

	8 May	9 May	11 May	Total
Number released	35	65	100	200
Number recaptured alive	33 (0.943)	63 (0.969)	96 (0.960)	192 (0.960)
Number recaptured dead	0 (0.000)	0 (0.000)	1 (0.010)	1 (0.005)
Tags only[1]	0 (0.000)	0 (0.000)	1 (0.010)	1 (0.005)
Predation	0 (0.000)	0 (0.000)	1[2] (0.010)	1 (0.005)
Unknown	0 (0.000)	2 (0.031)	0 (0.000)	2 (0.010)
Trapped[3]	2 (0.057)	0 (0.000)	1 (0.010)	3 (0.015)
Number held	33	63	96	192
Number alive at 48 h	33	63	96	192

1 - Recovery of dislodged inflated tags only, fish assumed dead.

2 - Black bird predation.

3 - Fish trapped at outfall, could not be safely retrieved.

Table 2-2

Daily tag-recapture data for juvenile salmonids released through Spillbays 4, 9, and 11 at The Dalles Dam, May 2001.

	23 May				24 May				25 May				
Spillbay:	***4***	***9***	***11***		***4***	***9***	***11***		***4***	***9***	***11***		
Discharge (kcfs):	***7.4***	***4.5***	***4.5***	***Combined***	***5.9***	***4.5***	***-***	***Combined***	***4.5***	***4.5***	***3.0***	***Combined***	***TOTAL***
90 to 102 mm (subyearling chinook)													
Number released	5	5	5	15	5	5	-	10	-	-	-	0	25
Number recaptured alive	5	3	3	11	2	5	-	7	-	-	-	0	18
Number recaptured dead	0	0	0	0	0	0	-	0	-	-	-	0	0
Tags only[1]	0	0	0	0	0	0	-	0	-	-	-	0	0
Unknown	0	0	0	0	2	0	-	2	-	-	-	0	2
Radio signal only	0	2	2	4	1	0	-	1	-	-	-	0	5
115 to 140 mm (rainbow trout)													
Number released	-	-	-	0	5	5	-	10	8	3	4	15	25
Number recaptured alive	-	-	-	0	5	5	-	10	7	3	4	14	24
Number recaptured dead	-	-	-	0	0	0	-	0	0	0	0	0	0
Tags only[1]	-	-	-	0	0	0	-	0	0	0	0	0	0
Unknown	-	-	-	0	0	0	-	0	0	0	0	0	0
Radio signal only	-	-	-	0	0	0	-	0	1	0	0	1	1
141 to 184 mm (rainbow trout)													
Number released	-	-	-	0	20	20	-	40	17	22	21	60	100
Number recaptured alive	-	-	-	0	18	19	-	37	17	22	19	58	95
Number recaptured dead	-	-	-	0	0	0	-	0	0	0	0	0	0
Tags only[1]	-	-	-	0	1	1	-	2	0	0	1	1	3
Unknown	-	-	-	0	1	0	-	1	0	0	0	0	1
Radio signal only	-	-	-	0	0	0	-	0	0	0	1	1	1

1 - recovery of inflated tags only; fish assumed dead.

Table 2-3

Summary of hydraulic conditions when juvenile salmonids and sensor fish were passed through the sluice (8 through 11 May) and Spillbays 4, 9, and 11 (22 through 25 May) at The Dalles Dam, 2001.

		Elevation (ft)		Discharge (kcfs)					
Date		**Forebay**	**Tailrace**	**Total Project**	**Spillbay 4**	**Spillbay 9**	**Spillbay 11**	**All Spillbays**	**Sluice**
08 May	*Minimum*	158.2	76.3	101.9	0.0	0.0	0.0	0.0	5.4
	Maximum	158.9	77.1	142.3	0.0	0.0	0.0	0.0	5.4
	Average	158.6	76.8	125.2	0.0	0.0	0.0	0.0	5.4
09 May	*Minimum*	158.9	76.0	103.1	0.0	0.0	0.0	0.0	5.4
	Maximum	159.1	77.0	145.9	0.0	0.0	0.0	0.0	5.4
	Average	159.0	76.6	130.3	0.0	0.0	0.0	0.0	5.4
11 May	*Minimum*	157.7	76.5	100.5	0.0	0.0	0.0	0.0	5.4
	Maximum	158.8	77.9	151.1	0.0	0.0	0.0	0.0	5.4
	Average	158.4	76.9	120.7	0.0	0.0	0.0	0.0	5.4
Pooled	*Minimum*	157.7	76.0	100.5	0.0	0.0	0.0	0.0	5.4
	Maximum	159.1	77.9	151.1	0.0	0.0	0.0	0.0	5.4
	Average	158.6	76.8	124.9	0.0	0.0	0.0	0.0	5.4
22 May	*Minimum*	158.2	76.5	140.6	6.0	4.5	0.0	58.0	5.4
	Maximum	159.6	77.0	147.5	6.0	4.5	0.0	58.0	5.4
	Average	158.8	76.7	145.6	6.0	4.5	0.0	58.0	5.4
23 May	*Minimum*	158.9	77.3	158.9	7.4	4.5	4.5	69.0	5.4
	Maximum	159.3	77.8	159.3	7.4	4.5	4.5	69.0	5.4
	Average	159.0	77.5	159.0	7.4	4.5	4.5	69.0	5.4
24 May	*Minimum*	157.8	78.4	174.5	5.9	4.5	3.0	54.0	5.4
	Maximum	158.4	78.8	183.2	5.9	4.5	3.0	54.0	5.4
	Average	158.1	78.5	178.8	5.9	4.5	3.0	54.0	5.4
25 May	*Minimum*	158.5	77.9	164.1	4.5	4.5	3.0	51.0	5.4
	Maximum	158.9	78.2	172.3	4.5	4.5	3.0	51.0	5.4
	Average	158.7	78.1	168.9	4.5	4.5	3.0	51.0	5.4
Pooled	*Minimum*	157.8	76.5	140.6	4.5	4.5	0.0	51.0	5.4
	Maximum	159.6	78.8	183.2	7.4	4.5	4.5	69.0	5.4
	Average	158.7	77.7	163.2	6.0	4.5	2.7	58.4	5.4

Table 2-4

Condition codes assigned to fish and dislodged balloon tags for fish passage survival evaluation.

FISH CODES

A	No visible marks on fish
B	Flesh tear at tag site(s)
C	Minor scale loss, 3 to 20% (%s for entire body in immediate recovery; for detailed injury examination %s are for section only)
D	Major scale loss, >20%
E	Laceration(s); tear(s) on body
F	Severed body parts
G	Hemorrhaging, bruised
H	Stressed (lethargic, swimming poorly or sporadically)
I	Spasmodic movement of body
J	Very weak, barely gilling, died within 60 minutes of recovery
K	Failed to enter system
L	Fish likely preyed on based on telemetry, and/or circumstances relative to Turb'N recapture
M	Substantial bleeding at tag site
N	Bulging or missing eye(s)
P	Observed predator attack or marks indicative of predator
Q	Other information
R	Replaced due to entrapment in unrecoverable locations (i.e., in rocks, gate slot; recovery time expired)
T	Trapped inside tunnel/gate well
V	Fins damaged (ripped, split, torn) or pulled from origin
W	Abrasion/scrape
X	No recovery information at all; fish remains unrecovered
Z	Radio telemetry or other information; fish remains unrecovered

DISSECTION CODES

B	Swim bladder ruptured or expanded
D	Kidneys damaged (hemorrhaging)
E	Broken bones obvious
F	Hemorrhaging internally
L	Organ displacement
N	Heart damage, ruptured, hemorrhaging, etc.
O	Liver damage, ruptured, hemorrhaging, etc.
R	Necropsied, no obvious injuries
S	Necropsied, internal injuries observed
W	Head removed, i.e., otolith

TURB'N TAG CODES (not used in database)

A	Fully inflated
B	Partially inflated
C	Pinhole, leaking
D	Burst
E	Not inflated at all

Table 3-1

Tag-recapture data on balloon tagged and sensor fish released through spillbays at The Dalles Dam, May 2001.

	Spillbay 4 *(4.5 to 7.4 kcfs discharge)*			**Spillbay 9** *(4.5 kcfs discharge)*			**Spillbay 11** *(3.0 to 4.5 discharge)*			**Combined**		
	Released	**Recaptured**	**Injured**	**Released**	**Recaptured**	**Injured**	**Released**	**Recaptured**	**Injured**	**Released**	**Recaptured**	**Injured**
Sub-yearling chinook salmon (90 to 102 mm TL, mean 94 mm)	10	7	0	10	8	2	5	3	0	25	18	2
Rainbow trout (115 to 140 mm TL, mean 130 mm)	13	12	1	8	8	0	4	4	2	25	24	3
Rainbow trout (140 to 184 mm TL, mean 162 mm)	37	35	0	42	41	6	21	19	1	100	95	7
Combined	**60**	**54**	**1**	**60**	**57**	**8**	**30**	**26**	**3**	**150**	**137**	**12**
Sensor fish	40	39	-	39	39	-	28	27	-	107	105	-

Table 3-2

Summary of visible injuries and loss of equilibrium to juvenile salmonids passed through the sluice and Spillbays 4, 9, and 11 of The Dalles Dam, May 2001. No control fish were released to adjust for non-passage effects.

	Number Released	Number Examined	Visible Injury		Loss of Equilibrium	
			Number	Percent	Number	Percent
Sluice	200	194	4*	2.1	2**	1.0
Spillbay 4	60	54	1	1.9	1	1.9
Spillbay 9	60	57	8	14.0	2	3.5
Spillbay 11	30	26	3	11.5	0	0.0
Combined Spillbays	150	137	12	8.8	3	2.2

* Injuries on only 1 fish could be attributed to sluice passage (see Appendix Table A-4).

** Not due to passage (see Appendix Table A-4).

FIGURES

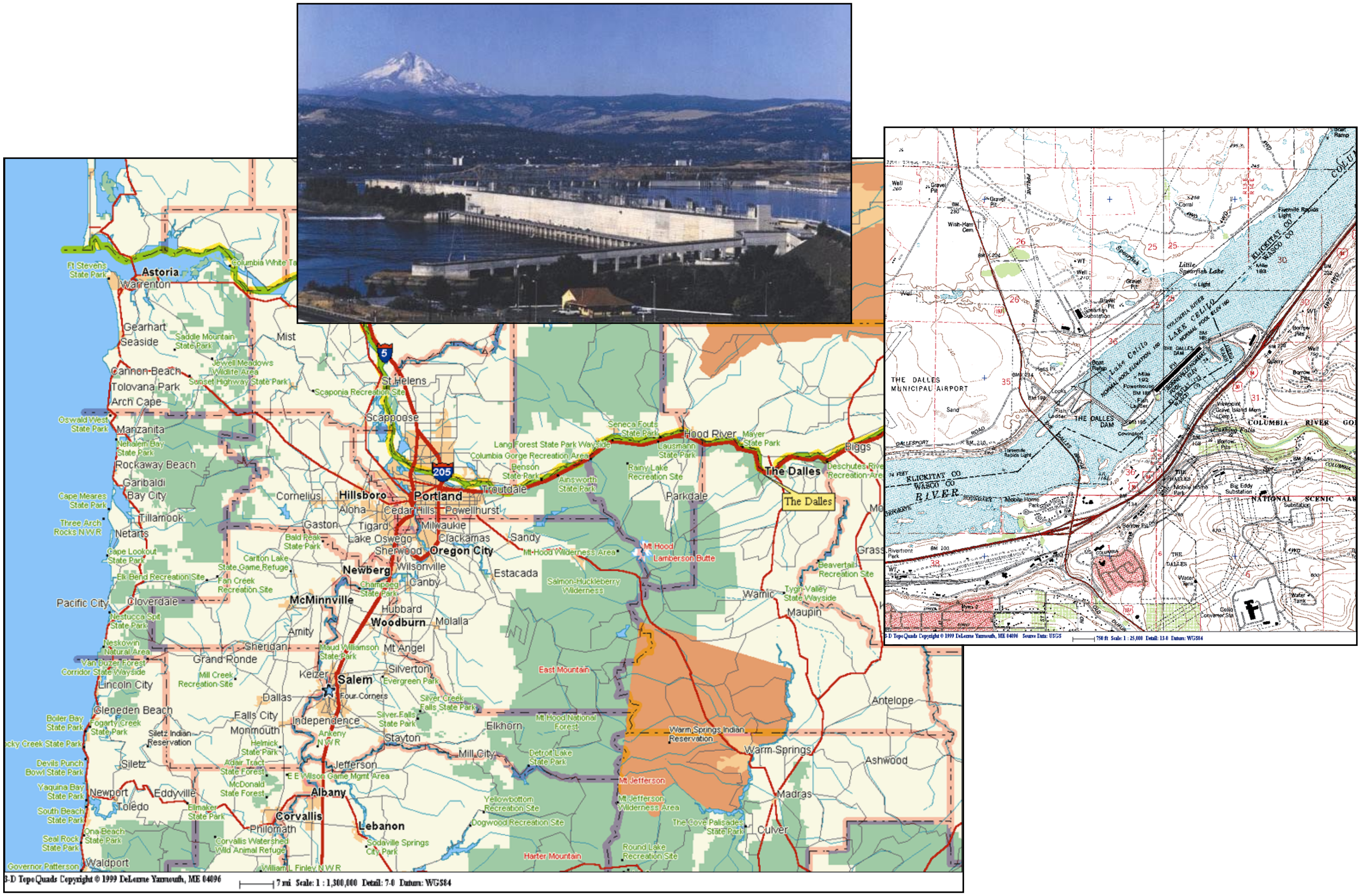


Figure 1-1

Location and general configuration of The Dalles Dam.

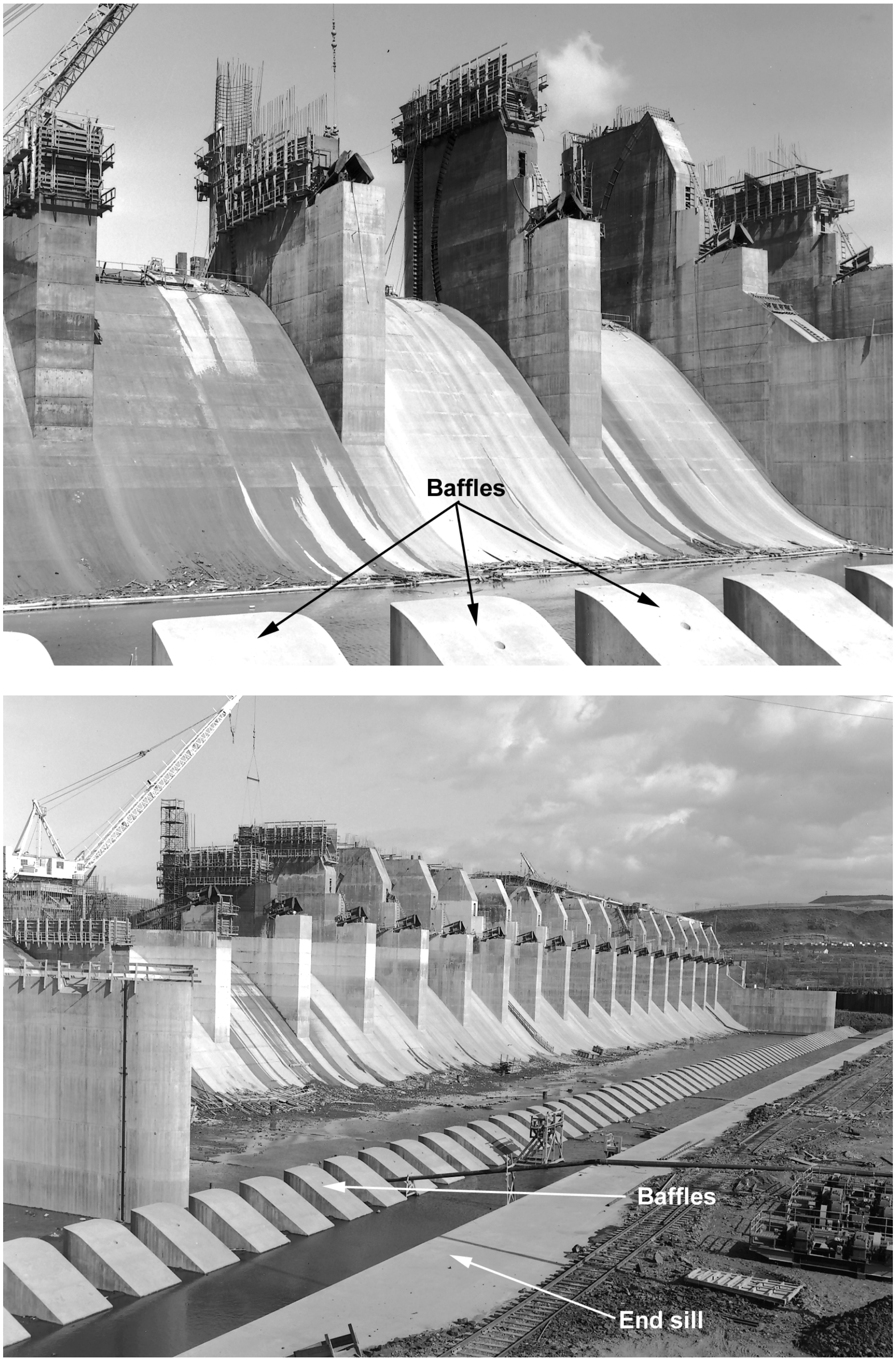


Figure 1-2

The Dalles Dam spillbay with energy dissipation structures (9 ft high baffles and 13 ft high vertical end sill. Photos provided by U.S. Army Corps of Engineers.

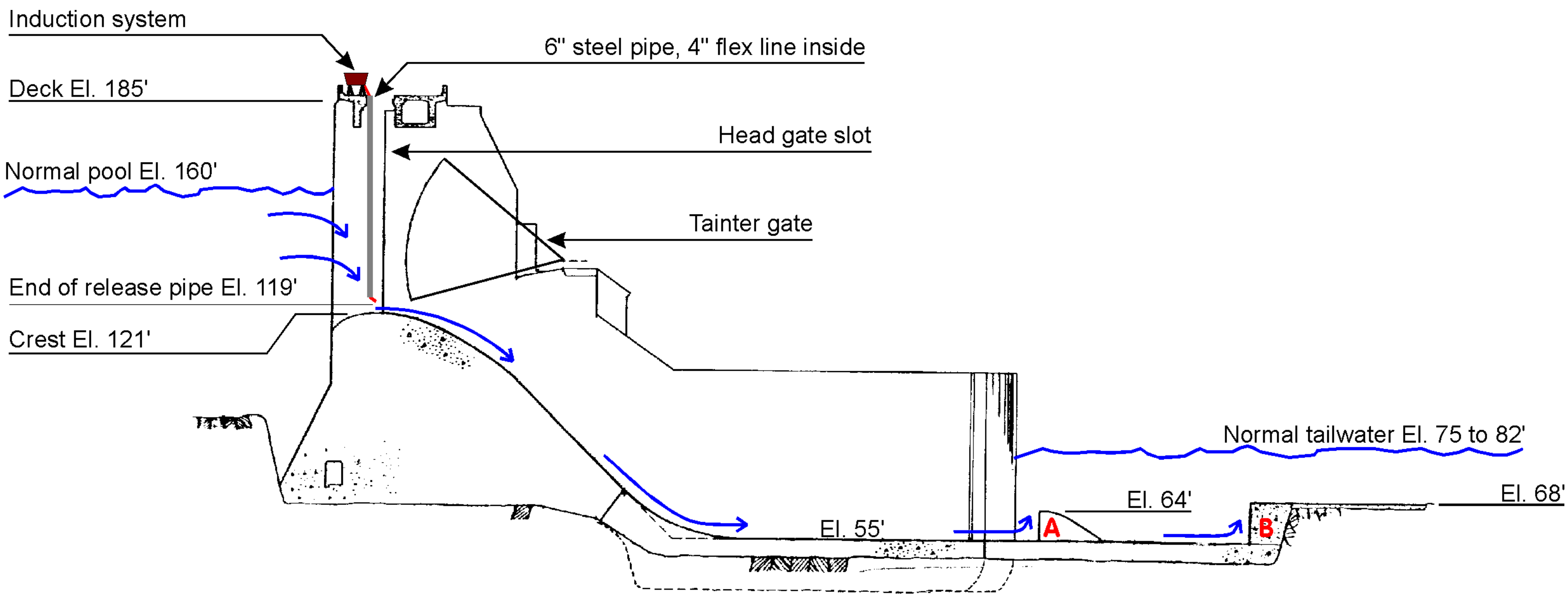
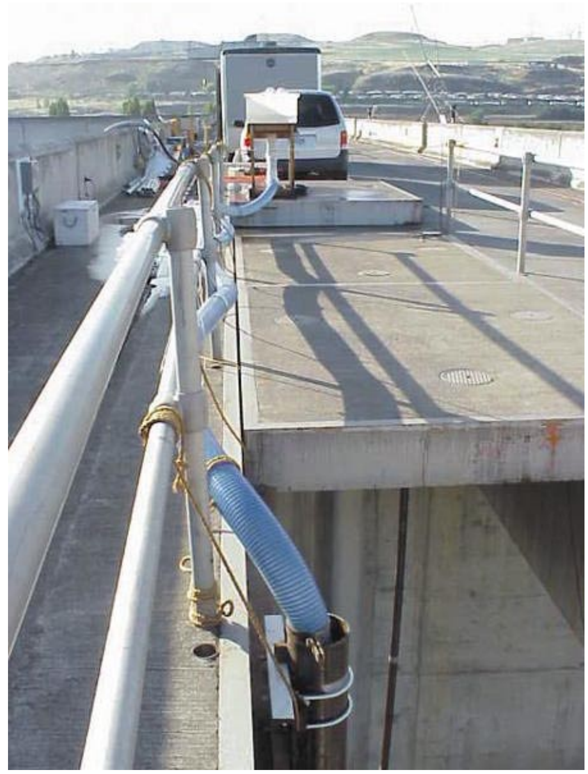


Figure 2-1

Cross section of spillbay showing release location for juvenile salmon and trout passed through Spillbays 4, 9, and 11 and energy dissipation structures (baffles-A, end sill-B) at The Dalles Dam, May 2001.

Sluice



Spillbay 9

Spillbay 11

Figure 2-2

Deployment of hoses to release balloon tagged juvenile salmonids into the sluice and spillbays at The Dalles Dam.

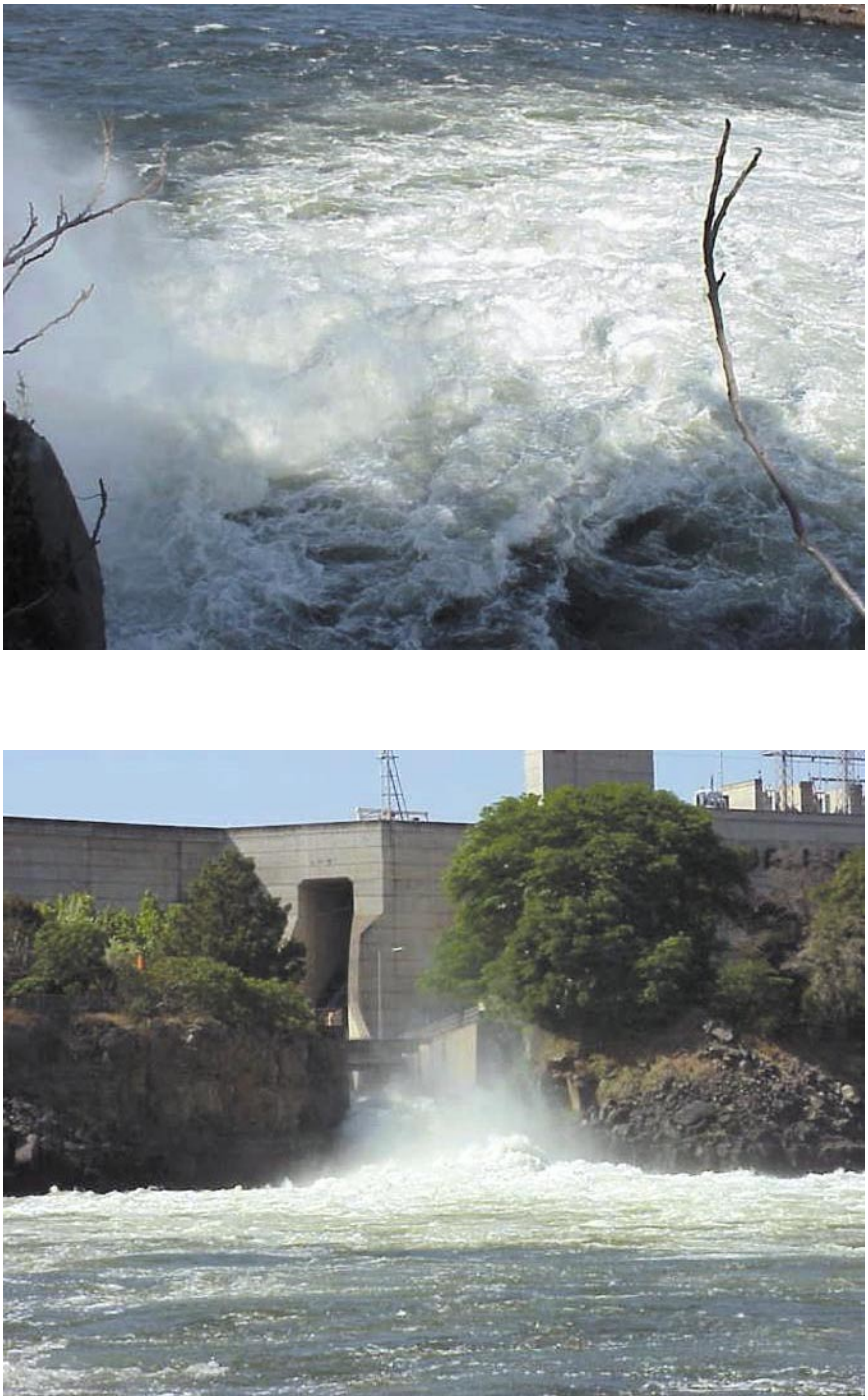


Figure 2-3

Hydraulic conditions at The Dalles sluice outfall during the passage of balloon tagged juvenile salmonids, May 2001.

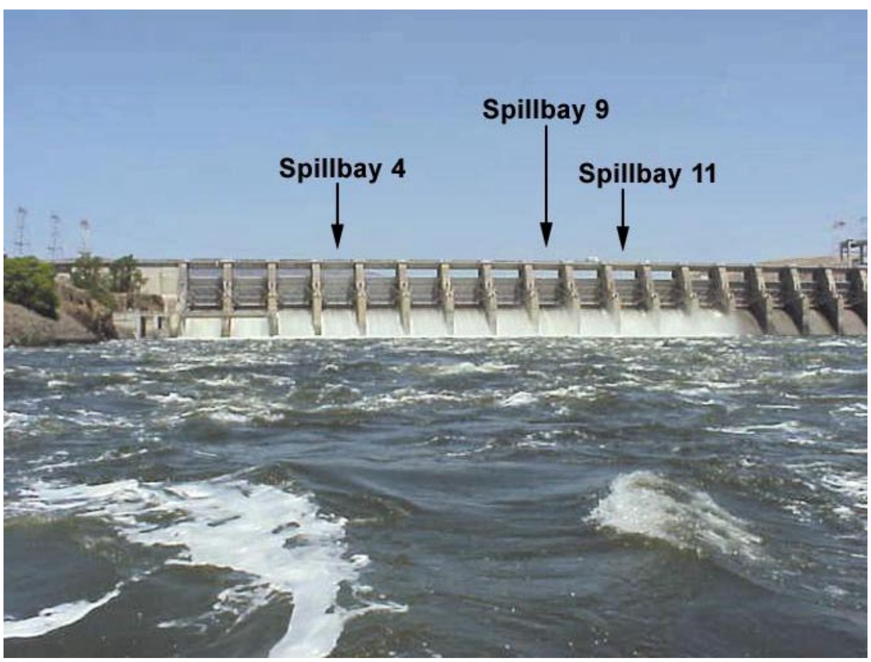
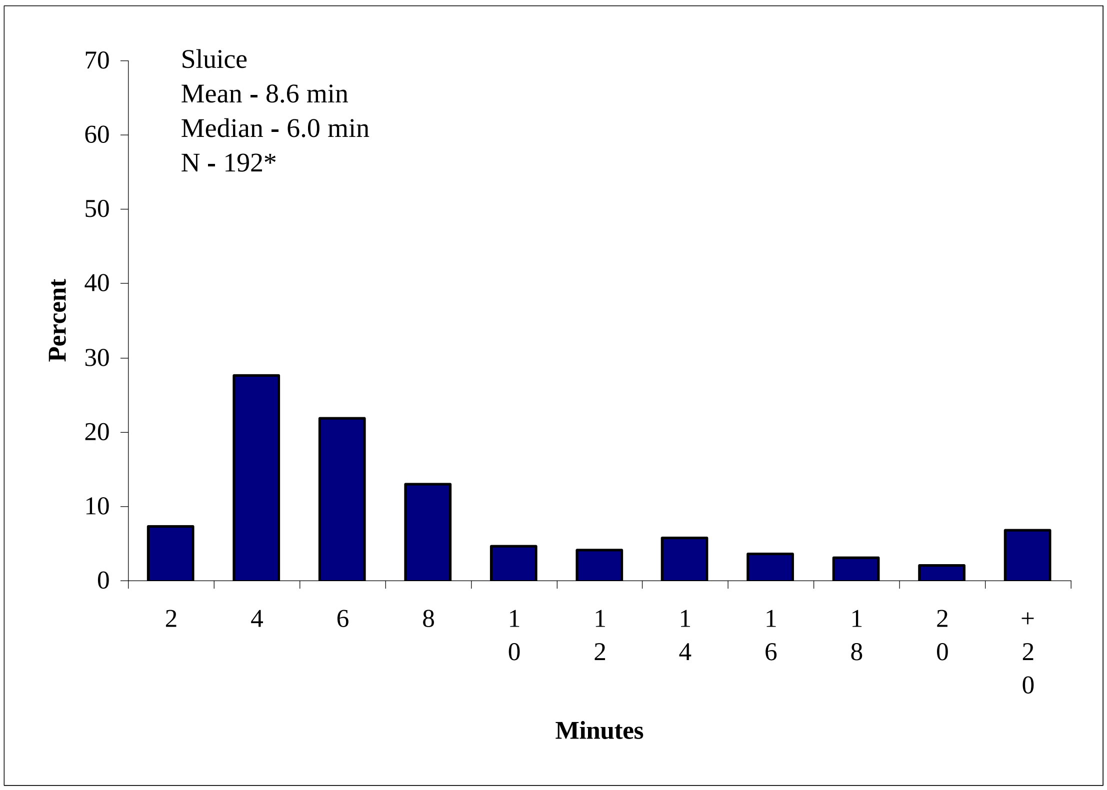


Figure 2-4

Hydraulic conditions downstream of The Dalles spillway during passage of balloon tagged juvenile salmonids through Spillbays 4, 9, and 11, May 2001.



* Two fish retained in outfall 2 to 4 hours excluded.

Figure 3-1

Frequency distribution of recapture times (minutes) of fish released through the sluice at The Dalles Dam, May 2001.

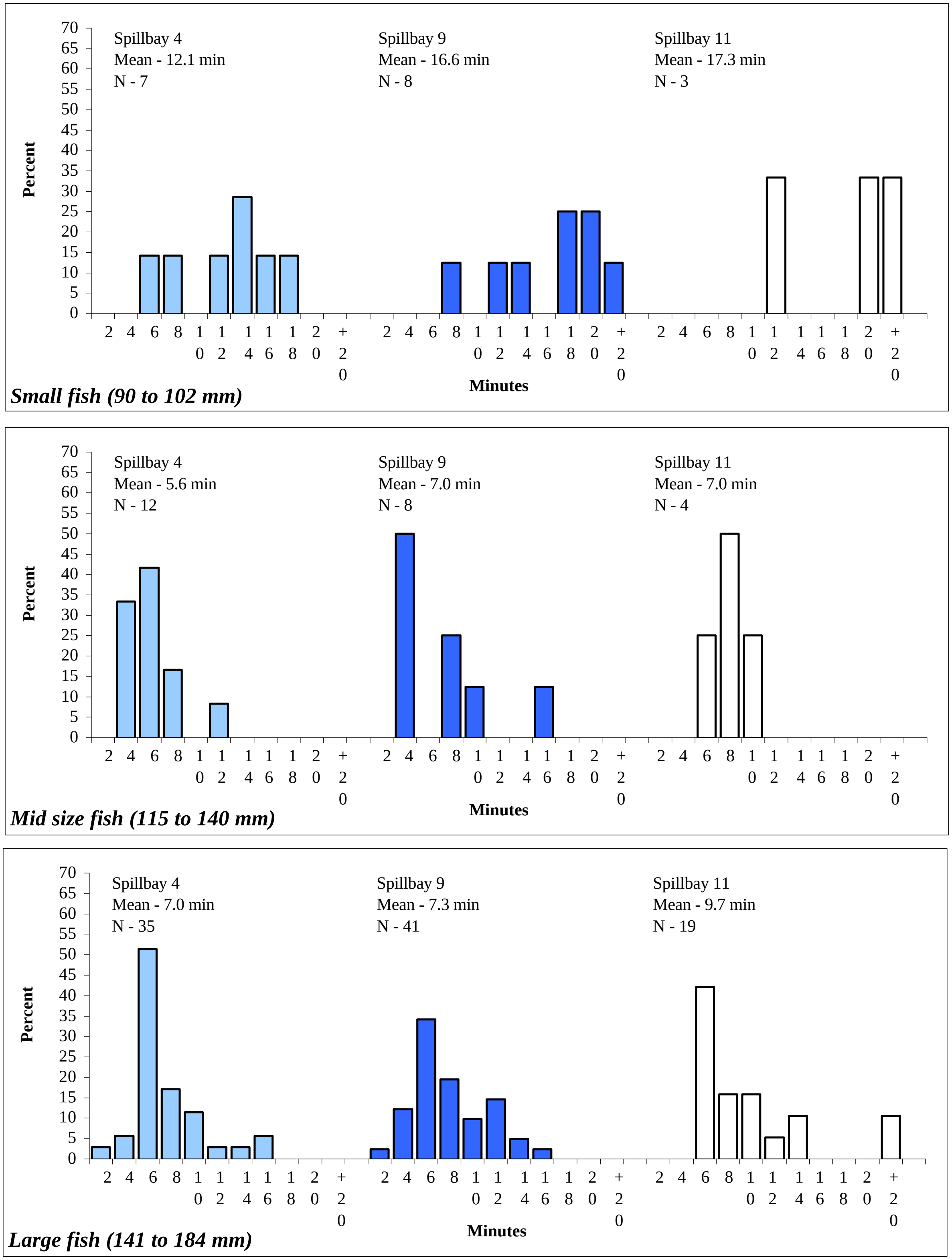
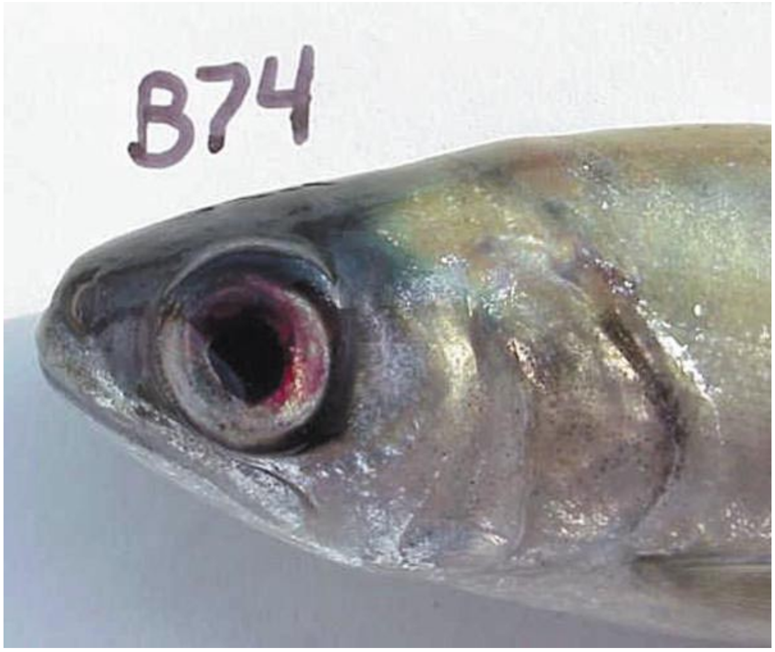


Figure 3-2

Frequency distribution of recapture times (minutes) of small, mid, and large sized fish released through Spillbays 4, 9, and 11 at The Dalles Dam, May 2001.



Sluice-passed

Spillbay-passed

Figure 3-3

Examples of injuries (hemorrhaged eye – upper photo, and scrape – lower photo) observed on juvenile salmonids after passing The Dalles sluice and spillway, May 2001.

APPENDIX A

HYDRAULIC/PHYSICAL CONDITIONS DURING TESTING, FISH INJURY DATA, INDIVIDUAL TRIAL DATA, AND DAILY FISH DISPOSITION DATA

Appendix Table A-1

Forebay and tailwater elevations (ft at msl) when condition was determined for juvenile chinook salmon passed through the sluice at The Dalles Dam, May 2001. Discharge through the sluice was maintained at 5.4 kcfs.

	8 May				9 May				11 May			
Time	**Forebay (ft)**	**Tailrace (ft)**	**Net Head (ft)**	**Total Project Discharge (kcfs)**	**Forebay (ft)**	**Tailrace (ft)**	**Net Head (ft)**	**Total Project Discharge (kcfs)**	**Forebay (ft)**	**Tailrace (ft)**	**Net Head (ft)**	**Total Project Discharge (kcfs)**
0800									157.8	76.5	81.3	117.8
0900					159.0	76.0	83.0	103.1	157.7	76.6	81.1	119.6
1000					158.9	76.0	82.9	110.7	157.9	76.6	81.3	116.1
1100	158.2	76.4	81.8	117.5	158.9	76.3	82.6	113.4	158.0	76.7	81.3	112.7
1200	158.4	76.3	82.1	101.9	159.0	76.5	82.5	129.1	158.1	76.8	81.3	114.3
1300	158.5	76.3	82.2	112.2	159.0	76.8	82.2	140.8	158.4	76.7	81.7	115.5
1400	158.5	76.7	81.8	123.6	158.9	76.9	82.0	142.9	158.5	76.7	81.8	115.4
1500	158.6	77.1	81.5	127.3	159.0	76.9	82.1	142.6	158.6	76.8	81.8	100.5
1600	158.8	77.0	81.8	138.2	159.0	76.9	82.1	145.9	158.8	76.8	82.0	117.9
1700	158.8	77.1	81.7	138.2	159.1	77.0	82.1	144.4	158.8	77.1	81.7	120.6
1800	158.9	77.1	81.8	142.3					158.8	77.9	80.9	146.9
1900									158.8	77.9	80.9	151.1
Average	*158.6*	*76.8*	*81.8*	*125.2*	*159.0*	*76.6*	*82.4*	*130.3*	*158.4*	*76.9*	*81.4*	*120.7*

Appendix Table A-2

Hydraulic conditions when juvenile salmon and sensor fish were passed through Spillbays 4, 9, and 11 at The Dalles Dam, May 2001.

	22 May						
	Elevation (ft)		Spillway Discharge (kcfs)				Total Project (kcfs)
Time	Forebay	Tailrace	Bay 4	Bay 9	Bay 11	All Bays	
0900	158.2	76.5	6.0	4.5	0.0	58.0	145.7
1000	158.4	76.5	6.0	4.5	0.0	58.0	145.2
1100	158.4	76.5	6.0	4.5	0.0	58.0	147.5
1200	158.6	76.6	6.0	4.5	0.0	58.0	146.1
1300	158.8	76.7	6.0	4.5	0.0	58.0	145.5
1400	158.9	76.7	6.0	4.5	0.0	58.0	147.5
1500	159.2	76.8	6.0	4.5	0.0	58.0	140.6
1600	159.4	76.8	6.0	4.5	0.0	58.0	144.8
1700	159.6	77.0	6.0	4.5	0.0	58.0	147.3
1800	-	-	-	-	-	-	-
Average	*158.8*	*76.7*	*6.0*	*4.5*	*0.0*	*58.0*	*145.6*
	24 May						
0900	158.0	78.8	5.9	4.5	3.0	54.0	180.1
1000	157.9	78.6	5.9	4.5	3.0	54.0	183.2
1100	157.8	78.5	5.9	4.5	3.0	54.0	175.5
1200	157.9	78.4	5.9	4.5	3.0	54.0	179.3
1300	157.9	78.5	5.9	4.5	3.0	54.0	179.8
1400	158.1	78.5	5.9	4.5	3.0	54.0	179.4
1500	158.1	78.5	5.9	4.5	3.0	54.0	174.5
1600	158.3	78.5	5.9	4.5	3.0	54.0	178.2
1700	158.4	78.5	5.9	4.5	3.0	54.0	178.1
1800	158.4	78.5	5.9	4.5	3.0	54.0	179.7
Average	*158.1*	*78.5*	*5.9*	*4.5*	*3.0*	*54.0*	*178.8*

	23 May						
	Elevation (ft)		Spillway Discharge (kcfs)				Total Project (kcfs)
Time	Forebay	Tailrace	Bay 4	Bay 9	Bay 11	All Bays	
0900	159.3	77.8	7.4	4.5	4.5	69.0	159.3
1000	159.1	77.5	7.4	4.5	4.5	69.0	159.1
1100	159.1	77.3	7.4	4.5	4.5	69.0	159.1
1200	159.0	77.4	7.4	4.5	4.5	69.0	159.0
1300	158.9	77.7	7.4	4.5	4.5	69.0	158.9
1400	159.0	77.5	7.4	4.5	4.5	69.0	159.0
1500	159.0	77.5	7.4	4.5	4.5	69.0	159.0
1600	159.0	77.4	7.4	4.5	4.5	69.0	159.0
1700	159.0	77.5	7.4	4.5	4.5	69.0	159.0
1800	159.0	77.5	7.4	4.5	4.5	69.0	159.0
Average	*159.0*	*77.5*	*7.4*	*4.5*	*4.5*	*69.0*	*159.0*
	25 May						
0900	158.6	77.9	4.5	4.5	3.0	51.0	168.0
1000	158.7	78.0	4.5	4.5	3.0	51.0	169.6
1100	158.5	78.2	4.5	4.5	3.0	51.0	164.1
1200	158.6	78.1	4.5	4.5	3.0	51.0	169.1
1300	158.7	78.0	4.5	4.5	3.0	51.0	169.6
1400	158.8	78.1	4.5	4.5	3.0	51.0	169.6
1500	158.8	78.2	4.5	4.5	3.0	51.0	172.3
1600	158.9	78.2	4.5	4.5	3.0	51.0	168.8
1700	-	-	-	-	-	-	-
1800	-	-	-	-	-	-	-
Average	*158.7*	*78.1*	*4.5*	*4.5*	*3.0*	*51.0*	*168.9*

Appendix Table A-3

Disposition of rainbow trout equipped with a stomach inserted radio tag (Lotek nano tag) and one externally attached balloon tag during spillbay passage tests at The Dalles Dam, 25 May 2001.

Fish ID Number	Length (mm)	Lotek Tag Number	Description
Spillbay 4			
A10	118	111/79	Fish not recovered
A22	128	111/81	Lost tag prior to release
A23	122	111/83	Lost tag prior to release
A24	120	111/87	Lost tag after release
Spillbay 9			
B5	125	111/83	Fish recovered with tag (stressed)
B15	132	111/89	Lost tag after release
Spillbay 11			
C5	124	111/79	Lost tag prior to release
C10	123	111/81	Fish recovered with tag
C15	119	111/89	Fish recovered with tag (stressed and scrape on head)

Appendix Table A-4

Incidence of injury and temporary loss of equilibrium observed on juvenile chinook salmon passed through the sluice at The Dalles Dam, May 2001.

Fish ID Number	Injury Description	Status
A36	Temporary loss of equilibrium; external bruises; fish trapped at out fall for >2 h before recapture	Alive
A38	Temporary loss of equilibrium; external scrapes; fish trapped in rock along shore approximately 20 min	Alive
A61	Temporary loss of equilibrium; caught in suspended fishing net along shore for approximately 18 min)	Alive
B21	Bird bill marks	Dead 1 h
B57	Temporary loss of equilibrium; fish washed up on shore approximately 5 min	Alive
B74	Bulging/hemorrhaged left eye	Dead 1 h

Appendix Table A-5

Incidence of injury and temporary loss of equilibrium observed on juvenile salmonids passed through Spillbays 4, 9, and 11 at The Dalles Dam, May 2001. Fish were not held for delayed assessment.

Fish ID Number	Spillbay	Discharge (cfs)	Injury Description	Immediate Status
			90 to 102 mm (subyearling chinook)	
B4	9	4,500	Hemorrhaged left eye	Alive
B5	9	4,500	Hemorrhaged right eye	Alive
			115 to 140 mm (rainbow trout)	
A14	4	5,900	Missing end of snout	Alive
A34	4	4,500	Loss of equilibrium	Alive
B5	9	4,500	Loss of equilibrium	Alive
5	11	3,000	Hemorrhaged left gill	Alive
15	11	3,000	Scrape on top of head; slight loss of equilibrium	Alive
			141 to 184 mm (rainbow trout)	
B1	9	4,500	Flap of skin on left operculum	Alive
B4	9	4,500	Scrape on top of head	Alive
B7	9	4,500	Scrape on left side from dorsal to ventral fin	Alive
B13	9	4,500	Loss of equilibrium	Alive
B16	9	4,500	Hemorrhaged left gill; torn operculum	Alive
B17	9	4,500	Scrape from head to dorsal fin; injured left eye	Alive
B19	9	4,500	Torn left operculum	Alive
18	11	3,000	Scrape on right side	Alive

APPENDIX B

STATISTICAL ANALYSIS

Proportions and 90% confidence limits for fish released at the Dalles Dam, May 2001.

Description	N	Affected	P	L90	U90
Small fish recovered across all the spillbays	25	18	0.72	0.53593	0.85563
Mid-sized fish recovered across all the spillbays	25	24	0.96	0.81126	0.99725
Large fish recoverd across all the spillbays	100	95	0.95	0.89446	0.97873
Injured fish recovered from Spillbay 11	26	3	0.1154	0.036039	0.27939
Injured fish recovered from Spillbay 4	54	1	0.0185	0.001269	0.09267
Injured fish recovered from Spillbay 9	57	8	0.1404	0.074437	0.24257
Large injured fish recovered from all the spillbays	95	7	0.0737	0.036702	0.13699
Mid-sized fish recovered from all the spillbays	24	3	0.125	0.039089	0.29966
Small injured fish recovered from all the spillbays	18	2	0.1111	0.023991	0.3197

Chi square and Fisher's Exact Test results for recovered and injured fish released at the Dalles Dam, May 2001.

Recapture of fish released at all the spillbays by size

Frequency Expected Cell Chi-Square	Not Recaptured	Recaptured	Total
Large fish	5 8.6667 1.5513	95 91.333 0.1472	100
Mid-Sized fish	1 2.1667 0.6282	24 22.833 0.0596	25
Small fish	7 2.1667 10.782	18 22.833 1.0231	25
Total	13	137	150

Statistics for Table of size by recapture

Statistic	DF	Value	Prob
Chi-Square	2	14.1915	0.0008
Likelihood Ratio Chi-Square	2	10.6792	0.0048
Mantel-Haenszel Chi-Square	1	10.362	0.0013
Phi Coefficient		0.3076	
Contingency Coefficient		0.294	
Cramer's V		0.3076	

WARNING: 33% of the cells have expected counts less than 5. Chi-square may not be a valid test.

Fisher's Exact Test	
Table Probability (P)	4.94E-04
Pr <= P	0.0035

Sample Size = 150

Chi square and Fisher's Exact Test results for recovered and injured fish released at the Dalles Dam, May 2001.

Recapture of all fish at different spillbays

Frequency Expected Cell Chi-Square	Not Recaptured	Recaptured	Total
Spillbay 11	4 2.6 0.7538	26 27.4 0.0715	30
Spillbay 4	6 5.2 0.1231	54 54.8 0.0117	60
Spillbay 9	3 5.2 0.9308	57 54.8 0.0883	60
Total	13	137	150

Statistics for Table spillbay by recapture

Statistic	DF	Value	Prob
Chi-Square	2	1.9792	0.3717
Likelihood Ratio Chi-Square	2	2.0349	0.3615
Mantel-Haenszel Chi-Square	1	1.9362	0.1641
Phi Coefficient		0.1149	
Contingency Coefficient		0.1141	
Cramer's V		0.1149	

Fisher's Exact Test	
Table Probability (P)	0.0257
Pr <= P	0.3574

Sample Size = 150

Chi square and Fisher's Exact Test results for recovered and injured fish released at the Dalles Dam, May 2001.

Injuries of fish released at several spillbays.

Frequency Expected Cell Chi-Square	Injured	Uninjured	Total
Spillbay 11	3 2.2774 0.2293	23 23.723 0.022	26
Spillbay 4	1 4.7299 2.9413	53 49.27 0.2824	54
Spillbay 9	8 4.9927 1.8114	49 52.007 0.1739	57
Total	12	125	137

Statistics for Table spillbay by injury

Statistic	DF	Value	Prob
Chi-Square	2	5.4603	0.0652
Likelihood Ratio Chi-Square	2	6.5642	0.0375
Mantel-Haenszel Chi-Square	1	0.8533	0.3556
Phi Coefficient		0.1996	
Contingency Coefficient		0.1958	
Cramer's V		0.1996	

WARNING: 33% of the cells have expected counts less than 5. Chi-square may not be a valid test.

Fisher's Exact Test	
Table Probability (P)	0.0042
Pr <= P	0.0503

Sample Size = 137

Chi square and Fisher's Exact Test results for recovered and injured fish released at the Dalles Dam, May 2001.

Injuries of fish released at all spillbays by size.

Frequency Expected Cell Chi-Square	Injured	Uninjured	Total
large	7 8.3212 0.2098	88 86.679 0.0201	95
mid	3 2.1022 0.3834	21 21.898 0.0368	24
small	2 1.5766 0.1137	16 16.423 0.0109	18
Total	12	125	137

Statistics for Table size by injury

Statistic	DF	Value	Prob
Chi-Square	2	0.7747	0.6788
Likelihood Ratio Chi-Square	2	0.7331	0.6931
Mantel-Haenszel Chi-Square	1	0.5422	0.4615
Phi Coefficient		0.0752	
Contingency Coefficient		0.075	
Cramer's V		0.0752	

WARNING: 33% of the cells have expected counts less than 5. Chi-square may not be a valid test.

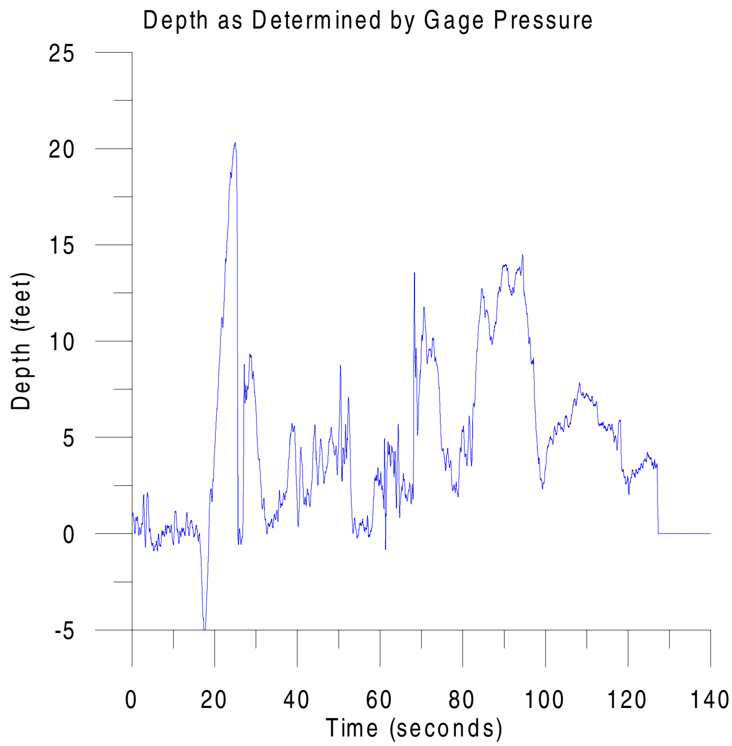
Fisher's Exact Test	
Table Probability (P)	0.0616
Pr <= P	0.5668

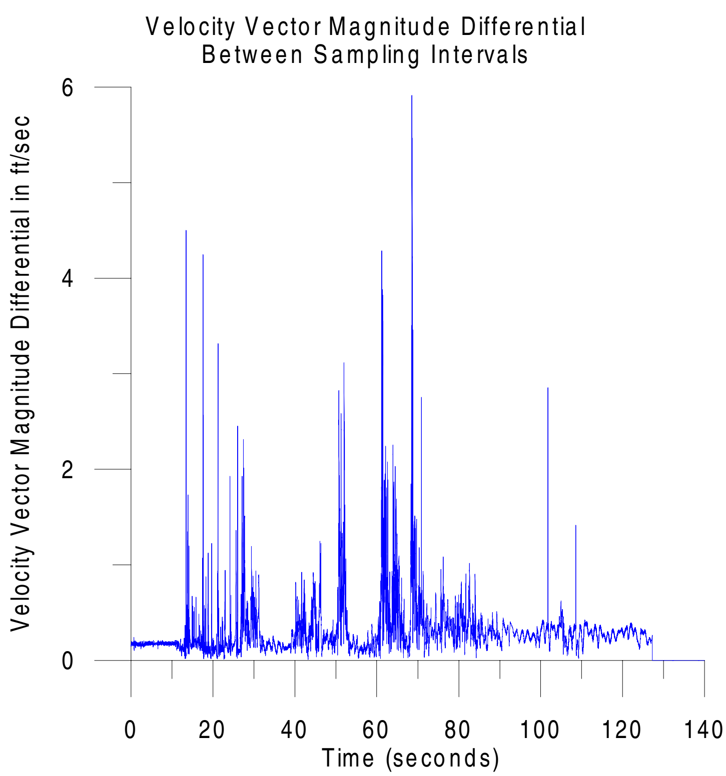
Sample Size = 137

APPENDIX C

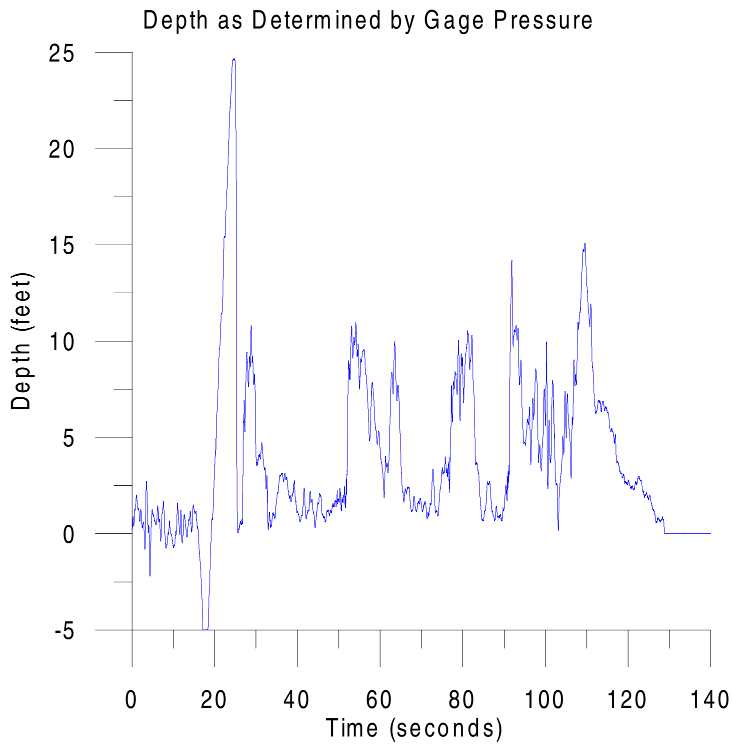
PRELIMINARY SENSOR FISH RESULTS

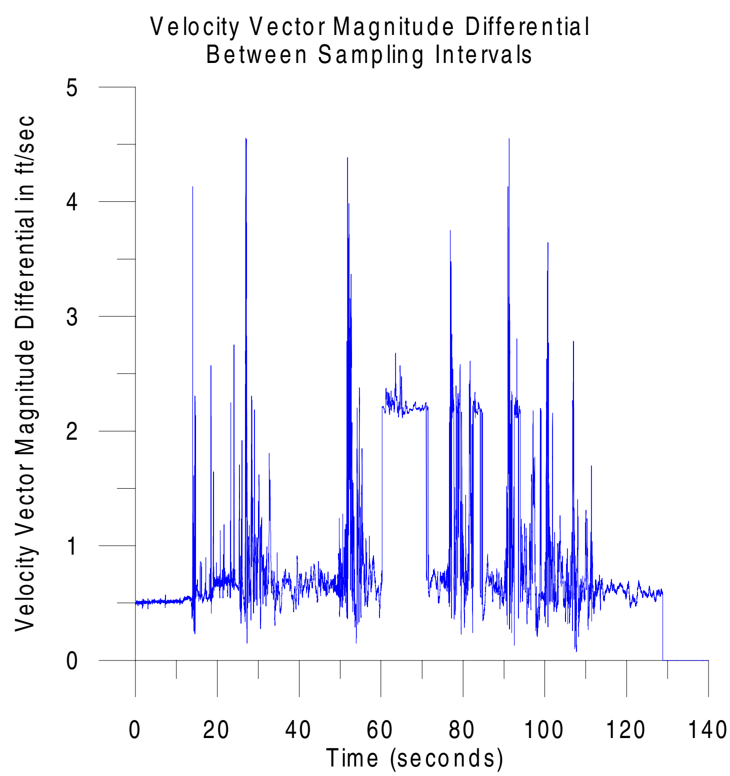
The Dalles Dam Spill Study
May 2001 - Sensor 605
Spillbay 9 - 4.5 kcfs



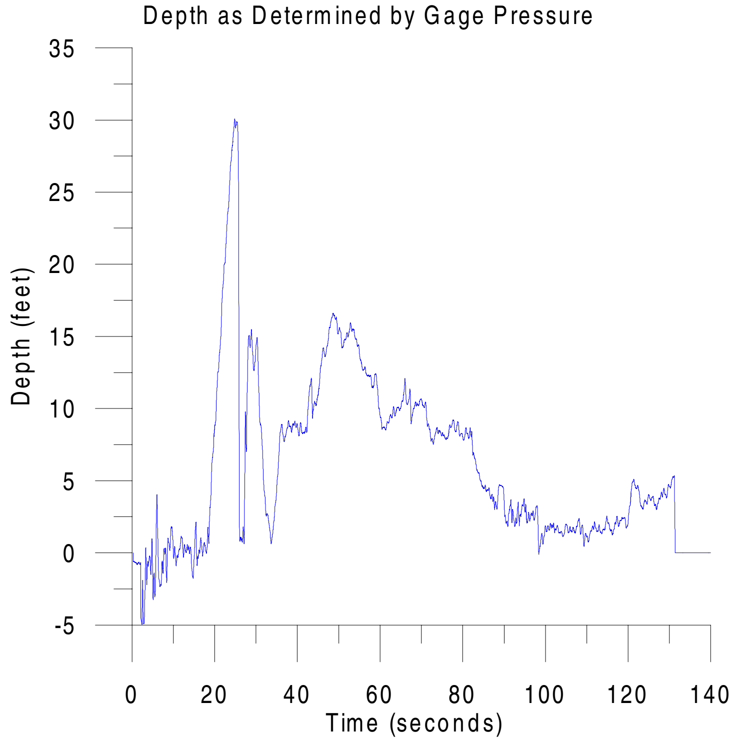


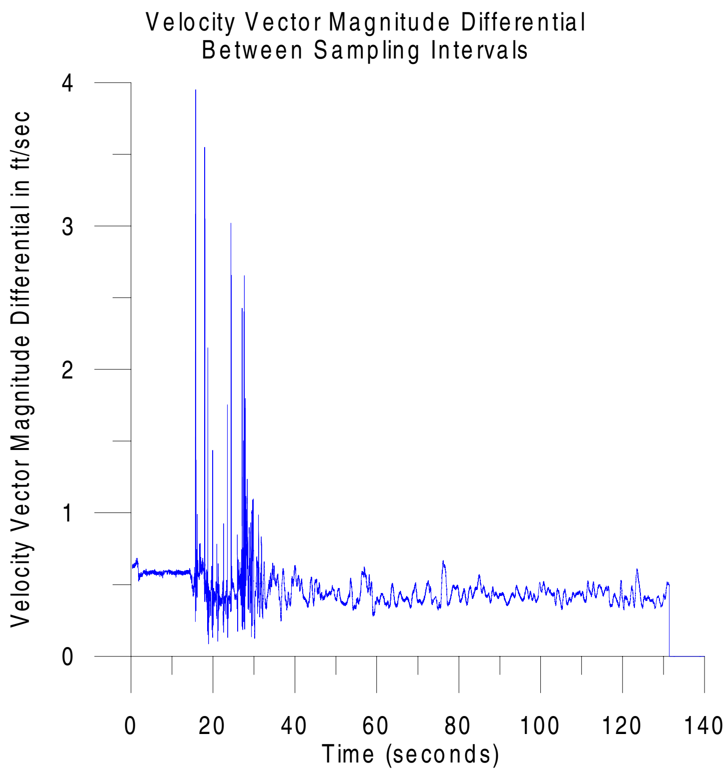
The Dalles Dam Spill Study
May 2001 - Sensor 503
Spillbay 9 - 4.5 kcfs





The Dalles Dam Spill Study
May 2001 - Sensor 504
Spillbay 4 - 4.5 kcfs





The Dalles Dam Spill Study
May 2001 - Sensor 504
Spillbay 4 - 7.4 kcfs